Abstracts of Technical Articles by Bell System Authors

Poles and Pole Treatment.[1] REGINALD H. COLLEY. Studies made of pole use and drainage on the southern pine forest have brought out that if the demand for poles 35-feet and longer were to continue at the present rate, a situation would soon develop in which these poles would be at a premium. It would seem wise to use as many circumference classes as possible and to broaden the use of poles of other species whenever it is practicable to do so. Successful full length treatment of red pine, lodgepole pine, western cedar and Douglas fir poles will help to broaden this use.

There has been a definite trend toward greater mechanization in pole production. Machine shaving smooths the pole surface and accelerates drying. Poles with square cut roofs and slab gains are all-purpose poles, one design taking the place of four. New types of preservative treatment—greensalt, creosote-petroleum-pentachlorphenol and salt-creosote—are of promise and must be considered, when current restrictions are removed, in those cases where clean poles are mandatory.

Interesting breaking test data are reported which show that the modulus of rupture of pole top sections average 90 per cent of the modulus of the poles as a whole, and that pole tops are sufficiently strong to meet their specified class breaking loads. This is of considerable importance where poles are guyed.

Current groundline treatment methods, it is pointed out, should be applied to untreated poles in line that are worth saving at the time of inspection, as a part of the regular inspection procedure.

Hearing, the Determining Factor for High-Fidelity Transmission.[2] HARVEY FLETCHER. This paper gives the requirements for ideal systems for the transmission of speech and music. These requirements are based on: 1. Measurements of the threshold and frequency limits of the hearing of more than 500,000 people at the New York and San Francisco World's Fairs; 2. measurements of the discomfort level of sound; 3. measurements of room noise in a wide variety of locations; and 4. measurements of the frequency limits and the maximum and minimum levels of speech, orchestral music, and various instruments of the orchestra.

From this information and from judgment tests it is concluded that substantially complete fidelity in the transmission of orchestral music is

[1] *Elec'l. Engg.*, Transactions Section, September 1942.
[2] *Proc. I. R. E.*, June 1942.

obtained by use of a system having a volume range of 65 decibels and a frequency range from 60 to 8000 cycles per second. Substantially complete fidelity for the transmission of speech is obtained by a system having a frequency range from 100 to 7000 cycles per second and a volume range of 40 decibels.

Preliminary experiments comparing a single-channel system and a two-channel stereophonic (auditory perspective) system showed that stereophonic transmission with an upper frequency limit of 5000 cycles per second was preferred to single-channel transmission with an upper limit of 15,000 cycles per second. A definite improvement was obtained in the stereophonic system by using three channels instead of two.

A New Direct Crystal-Controlled Oscillator for Ultra-Short-Wave Frequencies.[3] W. P. MASON and I. E. FAIR. An ultra-high-frequency crystal oscillator is described which utilizes a mechanical harmonic of an AT or BT crystal. With the oscillator frequencies as high as 197 megacycles, harmonics as high as the 23rd have been excited. Taking the second electrical harmonic of the oscillator, frequencies as high as 300 megacycles, or 1 meter have been obtained. Since a mechanical harmonic is used, the crystal can be of a practical size to handle and adjust. The harmonic vibration of the AT and BT crystals have as low a temperature coefficient as the fundamental mode, and temperature coefficients of less than two parts per million per degree centigrade are easily obtained. Stability curves for this type of oscillator are shown and the results indicate that at 120 megacycles stabilities in the same order of magnitude as for ordinary crystal oscillators can be obtained. Without temperature or voltage control it appears likely that the frequency should remain constant to $\pm$ 0.0025 per cent.

Some measurements have been made of the properties of harmonic crystals at high frequencies. It was found that the Q of a crystal is independent of the frequency but in general increases with harmonic order. The ratio of capacitances r of a crystal increases as the square of the harmonic order. It is shown that in order to obtain a positive reactance in the crystal $Q > 2r$. This relation will only be satisfied for harmonics of AT crystals less than the 7th. As a result oscillator circuits such as the Pierce circuit cannot be used to drive crystals at high harmonic frequencies. A discussion of oscillator circuits is given and it is shown that a capacitance-bridge oscillator circuit with the crystal in one arm is the best type to use for high-frequency harmonic crystals.

War Activities of the Bell Telephone System.[4] KEITH S. MCHUGH. The scope of the Bell System's nation-wide service is, even in peace, difficult to

[3] *Proc. I. R. E.*, October 1942.
[4] *Bell Telephone Magazine*, November 1942.

visualize in its entirety. In war, when practically every phase of the national effort to overthrow the Axis aggressors depends in some part on swift communication, both the extent and the importance of the System's contributions to the winning of the conflict are beyond summarizing. In the past two years, numerous articles in the *Bell Telephone Magazine* (listed at the end of this article), and in the employee publications of the Associated Companies, have described many aspects of the System's cooperation with the armed forces, with industry, and with the civilian population. Now, nearly a year after Pearl Harbor, it seems appropriate to review both the System's preparations for the national emergency and the steps which it has taken since war became no longer a threat but a fact. To the extent that it is possible in limited space, this article rounds out the previous fragmentary parts of the whole picture.

The Number of Two-Terminal Series-Parallel Networks.[5] JOHN RIORDAN and C. E. SHANNON. This paper is concerned with the number of ways n abstract (electrical) elements may be connected in series-parallel arrangements and in particular with the way the number behaves for n large. After a proof of a generating identity for the numbers given without proof by P. A. MacMahon in 1892, the paper gives recurrences and schemes of computation by means of which MacMahon's table for the numbers is extended from $n = 10$ to $n = 30$. The behaviour for n large is shown to be of the form

$$A\ \lambda^n\ n^{-3/2}$$

with A a fixed constant and λ a real number between $2 + \sqrt{2} = 3.414$ and 4 and closer to the former than the latter; indeed an approximating function for which λ is about 3.56 agrees with the numbers within 3% over the range 7 to 20. These results are used to show that almost all switching functions of n variables require at least

$$(1 - \epsilon)\ \frac{2^n}{\log_2 n} \qquad \epsilon > 0$$

switching elements (make or break contacts) in series-parallel realization.

The Electrical Oscillations of a Perfectly Conducting Prolate Spheroid.[6] ROBERT M. RYDER. The forced oscillations of a perfectly-conducting prolate spheroid of eccentricity nearly unity are shown to be decomposable into "harmonics" corresponding to different modes of vibration, each harmonic being quantitatively connected with a certain portion of the impressed electric field which drives the antenna. The harmonics contribute additively to the current and field of the spheroid; each offers a characteristic imped-

[5] *Jour. Mathematics and Physics*, August 1942.
[6] *Jour. Applied Physics*, May 1942.

ance to the driving field, and the properties of the antenna are a composite depending upon the proportions of the various harmonics present. The behavior of the harmonics with frequency is discussed qualitatively; analytical expressions obtained are useful chiefly at the resonant frequencies of the antenna, where the most important harmonic becomes sinusoidal in character.

On Radiation from Antennas.[7] S. A. SCHELKUNOFF and C. B. FELDMAN. This paper presents some theoretical remarks and experimental data relating to applications of the transmission-line theory to antennas. It is emphasized that the voltage, the current, and the charge are affected by radiation in different ways, a fact which should be considered in any adaptation of line equations to antennas.

It is shown experimentally and theoretically that in an antenna of length equal to an integral number of half wave-lengths, which is energized at a current antinode, the effect of radiation on the current and the charge (but not on the voltage) can roughly be represented by adding to the resistance of the wires another fairly simple term.

The Use of Secondary Electron Emission to Obtain Trigger or Relay Action.[8] A. M. SKELLETT. The use of secondary electrons to obtain trigger action similar to that of a thyratron is described. An experimental tube and the necessary circuits by which this action is achieved are discussed. This combination gives the features of a triode with a relay or on and off feature, resulting in an amplifier, oscillator, modulator, or other vacuum tube device which may be turned on or off abruptly at high or low frequencies. In addition, it can be used to replace thyratrons in many of their circuits where very low impedance is not necessary and is capable of much greater speeds of operation in such applications.

A New Frequency-Modulation Broadcasting Transmitter.[9] A. A. SKENE and N. C. OLMSTEAD. A new frequency-modulation transmitter is described which uses a novel amplifier circuit permitting an unusually simple mechanical design and an economical vacuum-tube complement.

The choice and design of circuit components, governed by both mechanical and electrical considerations, are discussed in detail.

A Secondary Frequency Standard Using Regenerative Frequency-Dividing Circuits.[10] F. R. STANSEL. A secondary frequency standard is described

[7] *Proc. I. R. E.*, November 1942.
[8] *Jour. Applied Physics*, August 1942.
[9] *Proc. I. R. E.*, July 1942.
[10] *Proc. I. R. E.*, April 1942.

in which standard frequencies are derived from a 5-megacycle oscillator by a series of frequency dividers. The advantage of obtaining standard frequencies by frequency division rather than by frequency multiplication is pointed out and the characteristics of the regenerative frequency dividers used are discussed.

Some Mechanical Aspects of Telephone Apparatus.[11] J. D. TEBO and H. G. MEHLHOUSE. *Part I.* It is seldom realized that the vastness of the Bell System requires such an enormous amount of equipment and wires for handling the 100,000,000 calls per day made by the people in the United States. A total of 44,000 kinds of apparatus involving 170,000 different parts are required. The crossbar switch, described in this article, is the specific telephone switching mechanism used in the latest dial telepbone system.

Of particular interest in the crossbar switch is the design of contact springs. These springs are essentially thin, metal beams of a rectangular cross section but of varying cross sectional area along their length. They are clamped at one end and are subject to bending as compound cantilevers. Since the clamping is necessarily between relatively soft insulating materials, the determination of the effective length of the spring in determining its true deflection curve required the use of unique methods. Likewise, since the springs are punched out of sbeet stock at an angle to the grain direction of the material, the modulus of elasticity does not remain the same for equal cross sections of the same material. Consideration of these points was necessary in determining the strength of the magnets for operating the contact springs, as well as to insure that the stresses introduced in the springs would not be excessive.

To study the motions of the various parts of tbe switch, both high speed motion pictures and the "rapid record" oscillograph were used. The oscillograph was provided with means for obtaining "sbadowgrams" of the actual movement of parts simultaneously with the changes in the electrical characteristics of the magnets and contacts. The use of both the camera and oscillograph provided valuable data for making improvements, both in design and operating characteristics.

Part II. The manufacture of crossbar apparatus is accomplished on a product basis; that is, the entire range of manufacturing operations is segregated into one division, and practically all operations from raw material to the completed product are performed in this division. More than 150 kinds of parts totaling an annual demand of 200,000,000 individual pieces are required to produce the crossbar switches.

To produce these parts requires a number of special machines, tools, and

[11] *Mech. Engg.*, May 1942 and June 1942.

operations. Of particular interest are the use of special progressive punch and die tools, coil winding, contact welding and conveyorized assembly and adjustment.

The use of heavy presses with large progressive punches and dies was necessitated by the degree of accuracy required for this grade of equipment. For example, the vertical unit base, weigbing only $\frac{3}{4}$ lb., is produced by a 75,000 lb. press, using a 3,500 lb. tool. Again, since 40,000,000 contact springs are required annually, each of which must be attached to insulators, automatic presses, conveyor belts and bandling devices are required. Welding two contacts on each spring is accomplished by special welding presses using rolls of contact metal tape, each contact being cut off just prior to the welding process. A quality of less than one defective contact out of 20,000 is maintained.

The coils are wound in special machines in "sticks" of 5 to 7 coils with .0007 inch thick cellulose acetate between each layer. A wire of a gage size halfway between # 37 and # 38 B & S is used on most of the coils because of critical capability conditions—the annual amount of wire of this size being 125,000 lbs.

Assembly and adjustment of the switches proceeds on conveyor belts from one end of a large room to the other—the procedure being set up in such a way as to create a continuous flow of completed parts for wiring into the large frames ready for installation in telephone exchanges.

Regulated Rectifiers in Telephone Offices.[12] D. E. Trucksess. For many years rectifiers of the garage type were used in converting alternating current to direct current for charging batteries used for communication purposes. These batteries furnish power for relay operation, for talking, and filament and plate supplies for repeaters. The rectifiers were of the manual-control type where the operator selected the charging current by means of tap switches or rheostats.

With the development of the thyratron type of tube, a rectifying means was made available in which the grid of the rectifier tube could be used to control its own output current by an electronic circuit. Rectifier circuits were designed to maintain a constant output voltage. If a regulated rectifier is connected to a battery and the constant rectifier voltage is 2.15 volts per cell, the load current will automatically come from the rectifier and not from the battery. Also the battery will draw from the rectifier sufficient additional current to maintain its charge. If the circuit voltage is held within limits of less than plus or minus one per cent, the maintenance of the battery is reduced and its life is extended.

The thyratron tube differs from the vacuum tube in that the grid does

[12] *Elec'l. Engg.*, Transactions Section, August 1942.

not have a continuous control of the plate current. When a positive potential is applied to the plate, current does not flow until the magnitude of the negative grid voltage is reduced to the critical value, at which time the plate current flows, and the magnitude of the plate current depends upon the voltages and impedances in the circuit. The grid has no further control, and plate current flows until it is stopped by reducing the plate voltage to zero.

Thyratron tubes use various gases and mixtures of gases. The earliest type used mercury vapor, but this type of tube is quite sensitive to temperature changes. The grid characteristics are shifted materially by changes in the room temperature in which it is operated, and in low temperatures it is almost a vacuum tube. Thyratron tubes using argon gas are not affected by temperature changes, but high-pressure argon tubes have a low inverse voltage which limits their application to low-voltage rectifiers. Tubes using low-pressure argon have a higher inverse voltage, but are accompanied by a high arc drop which makes their efficiency low. A mixture of mercury vapor and argon has been found which provides the temperature-stable grid characteristic of the argon tube and the low arc drop of the mercury-vapor tube. This type of tube has been very successful with certain regulating circuits, particularly at voltages less than 60 volts.

Five kinds of regulating circuits are used in telephone offices to hold the output voltage of rectifiers constant. The selection of the circuit to be used depends upon the magnitude of the current, d-c voltage, and type of rectifying means to he used. Two forms of regulating circuits using thyratron tubes and one using two-element high-pressure tubes were developed. A fourth circuit using all vacuum tubes was adapted for telephone use. The fifth kind uses a negative resistance.

In this paper a table shows the voltage and current output, type of control of the rectifiers, and the rectifying means that have found widespread use in the Bell System.

The regulated rectifier finds its applications in telephone offices where constant voltage, independent of load and a-c line-voltage variations, is required to supply filament grid bias and plate voltage to telephone repeaters. Certain measuring circuits require a regulated rectifier to supply a stabilized voltage. Regulated rectifiers also find applications where constant voltage is of secondary importance but an automatic power plant is desired for maintaining storage batteries in a fully charged condition to be ready to supply the power for telephone offices if the a-c power fails. A further compensation of regulating the voltage is the increase in life obtained from storage batteries if they are not continually being charged and discharged but are fully floated.